International Advanced Level Geography

Unit 3 Contested Planet
WGE03

Topic A1: Atmosphere and Weather Systems

Topic Guide Booklet

Contents

Introduction

Unit 3: Contested Planet
Topic A1: Atmosphere and Weather Systems

This booklet has been written to support teachers and learners teaching and studying the International Advanced Level Geography qualification.

This guide should be used alongside other published teaching and learning materials available on the IAL Geography web page.

Videos / animations:
This Topic Booklet contains some links to videos and animations within YouTube. To view these without distracting comments and adverts being visible, copy and paste the URL into http://viewpure.com/

The Big Picture

The Atmosphere and Weather Systems topic has three Enquiry Questions which must be covered. Enquiry Questions 1 and 2 are focused on physical process understanding, whereas Enquiry Question 3 is focused on management of extreme weather.

EQ1 Weather, climate and the global climate system	EQ2 Causes of extreme weather events	EQ3 Managing extreme weather risk.
• Weather and climate • Global circulation • Precipitation • Air masses • ITCZ • Jet stream / Rossby waves	• Depressions • Anticyclones • Tropical cyclones • Drought	• Forecasting • Players • Prediction, warning and evacuation • Engineering • Managing drought • Governance

Assessment
Topic A1 is assessed in Unit 3 Contested Planet by either:

- A 10 mark data stimulus question

Or

- A 10 mark data stimulus question + a 15 mark essay style question.

In an exam series where there is not a 15 mark essay style question on Topic A1, there will be one on Topic A2.
In addition Topic A1 may form part of the content for the 15 mark Synoptic question (Question 3 on the exam paper). Please see the accompanying **Assessment Guide for Unit 3 Contested Planet** for further details.

3.3.1 Global atmospheric circulation

Enquiry question: What are weather and climate and how are they influenced by the global climate system?

Weather versus climate

"Climate is what you expect, weather is what you get"

This well-known phrase neatly sums up the difference between weather and climate – a source of confusion among students:

- Climate refers to the average annual conditions of a place, with reference to precipitation and temperature (and other metrics such as sunshine hours, air pressure). Usually 30 years worth of data are required to calculate climate averages.
- Weather is the day to day variation in atmospheric conditions of a place.

The climate data below is for Toronto in Canada. These are averages for the period **1981-2010.** Toronto's climate is markedly seasonal in terms of temperature, but precipitation is much less seasonal varying from 53.7 mm to 84.7 mm.

In June, people in Toronto might ***expect*** temperatures of around 19°C with an average daily low of about 15°C. However, the record June low is -2.2°C. The record January high temperature is +16.1°C. Those record days show how the weather was not what was expected based on the average climate.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily mean °C	−3.7	−2.6	1.4	7.9	14.1	19.4	22.3	21.5	17.2	10.7	4.9	−0.5	**9.4**
Average precipitation mm	61.5	55.4	53.7	68.0	82.0	70.9	63.9	81.1	84.7	64.4	84.1	61.5	**831.1**

The atmosphere

Almost all of the world's weather takes place in the lowest layers of the atmosphere, the **troposphere,** which extends to an altitude of about 20 km at the equator and 7 km at the poles:

- The troposphere contains about 75% of all of the mass of atmospheric gases and 99% of all water vapour.
- The upper limit of the troposphere is a boundary layer called the **tropopause**; here temperature stops falling with increasing altitude (a temperature inversion).

- Above the tropopause is the **stratosphere**.
- Only very major thunderstorms can reach into the lower stratosphere, as well as major volcanic eruptions clouds.
- The **ozone layer,** containing a concentration of O_3, is found between 20-30 km altitude in the stratosphere.

Gases in the atmosphere have various functions:

Name	Formula	Percentage %	What is does
Nitrogen	N_2	78.1	Required for plant growth
Oxygen	O_2	20.9	Animal / human respiration
Ozone	O_3	Trace	Filters out some harmful UV rays
Argon	Ar	0.9	Trace gas
Carbon dioxide	CO_2	0.04	Greenhouse gas; reflects outgoing radiation back to earth. Plant respiration and growth
Neon	Ne	0.002	Trace gas
Helium	He	0.0005	Trace gas
Methane	CH_4	0.0002	Greenhouse gas; reflects outgoing radiation back to earth
Water vapor	H_2O	0.001% – 5%	Cloud formation; scatters some incoming radiation back into space

A question of scale?
One important point about atmospheric gases is how much their volume has changed as a result of human activity.

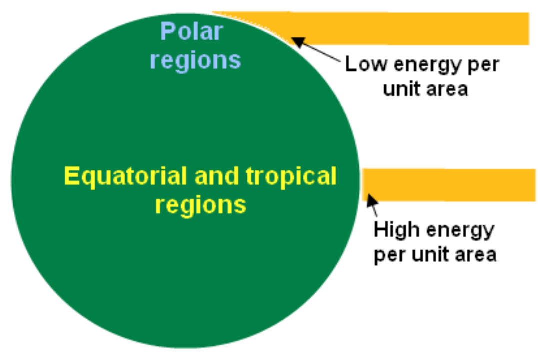
- **Carbon dioxide** has increased from 0.027% to 0.04% as a result of human pollution since about 1850.
- This is a percentage change of **48%**.

If the amount of oxygen in the atmosphere changed by the same volume (0.013%) it would be a barely noticeable percentage decrease or increase on the 20.9% of the atmosphere that is oxygen. The concern about carbon dioxide levels is a result of the large **percentage change** in concentration.

Carbon dioxide is responsible for the **greenhouse effect** along with water vapour and other gases. Incoming short-wave radiation from the sun passes through CO_2 on its way to the earth's surface. However, some outgoing longwave radiation is reflected off CO_2 back to earth's surface. The additional reflected heat gives the earth a **habitable** average temperature of 14°C. Without the greenhouse effect the average temperature would be around -15 to -18 °C i.e. not habitable. **The greenhouse effect is a natural, beneficial process.**

General circulation of the atmosphere

A very important concept is the general circulation of the atmosphere. Because earth is a rough sphere, its surface is heated by solar radiation differentially:



- **Equatorial and tropical areas** receive high amounts of solar radiation (sunshine) per unit area because the earth's surface here is at roughly 90° to incoming sunlight.
- **Polar areas** receive very low levels of solar radiation because of the low angle of incidence.

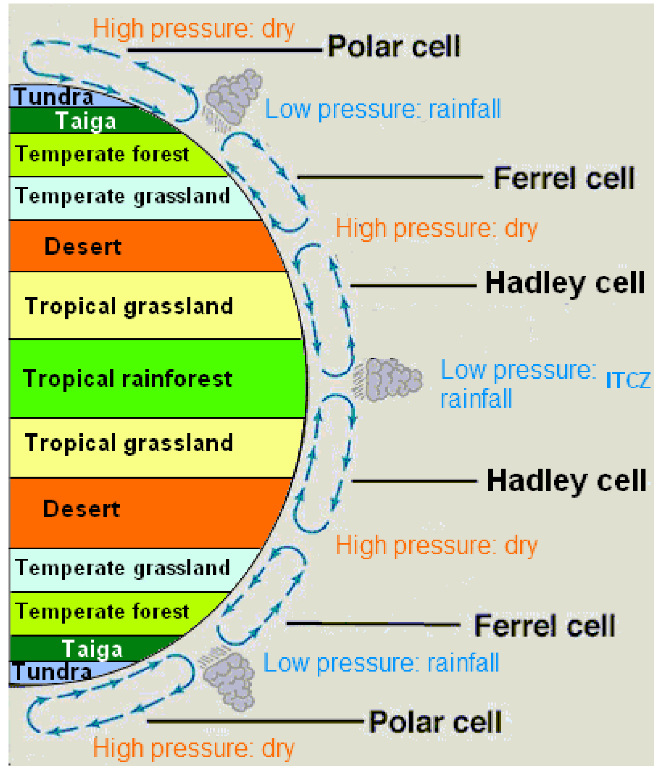
These differences mean:

- An excess of heat in low latitudes.
- A heat deficit in high latitudes.

Heat is **transferred** / **redistributed** from equatorial / tropical areas towards the poles, to 'even-up' surface temperatures by two main mechanisms:

1. Ocean currents
2. Atmospheric circulation (winds and air masses)

Atmospheric heat transfer takes place within three atmospheric cells in each hemisphere (often called the **tricellular model**). This model is disrupted by the distribution of oceans and continents but key features of it are:



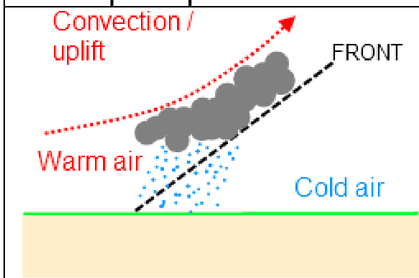
- Hadley, Ferrel and Polar cells.
- A pattern of low-high-low-high air pressure zones from the equator to the poles.
- Zones of high (low air pressure) and low precipitation (high air pressure).
- An area of persistent low air pressure near the equator (the equatorial low / Inter-tropical Convergence Zone (ITCZ) with high rainfall, that moves seasonally.
- A strong relationship between atmospheric cells, air pressure and rainfall / precipitation and the biomes found at particular latitudes.

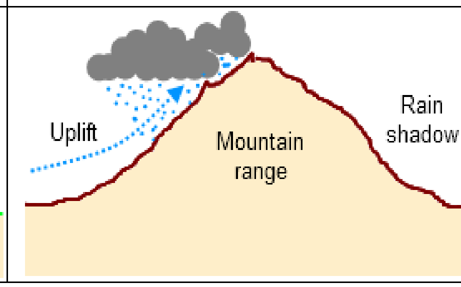
Search for 'Geography Classics: Global Atmospheric Circulation' on www.youtube.com

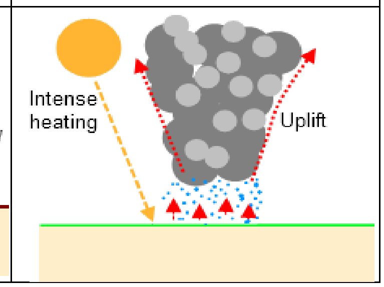
Precipitation
Precipitation includes rainfall, snowfall, sleet, hail, drizzle and fog. Precipitation is highly variable:
- Many locations have seasonal precipitation, such as monsoons and rainy seasons followed by dry seasons.
- Areas with persistent high air pressure receive little precipitation
- Places can get summer rainfall followed by winter snowfall.

There are main causes of precipitation:

FRONTAL	OROGRAPHIC	CONVECTIONAL
Warm air rises over cool / cold air at a weather front, leading to the warm air cooling, condensing to from cloud and then precipitation.	Air is forced to rise over hills or a mountain range, the air cools, condenses, clouds form and rain results.	Intense heating of the ground by the sun causes local convection and the generation of thunderstorms.





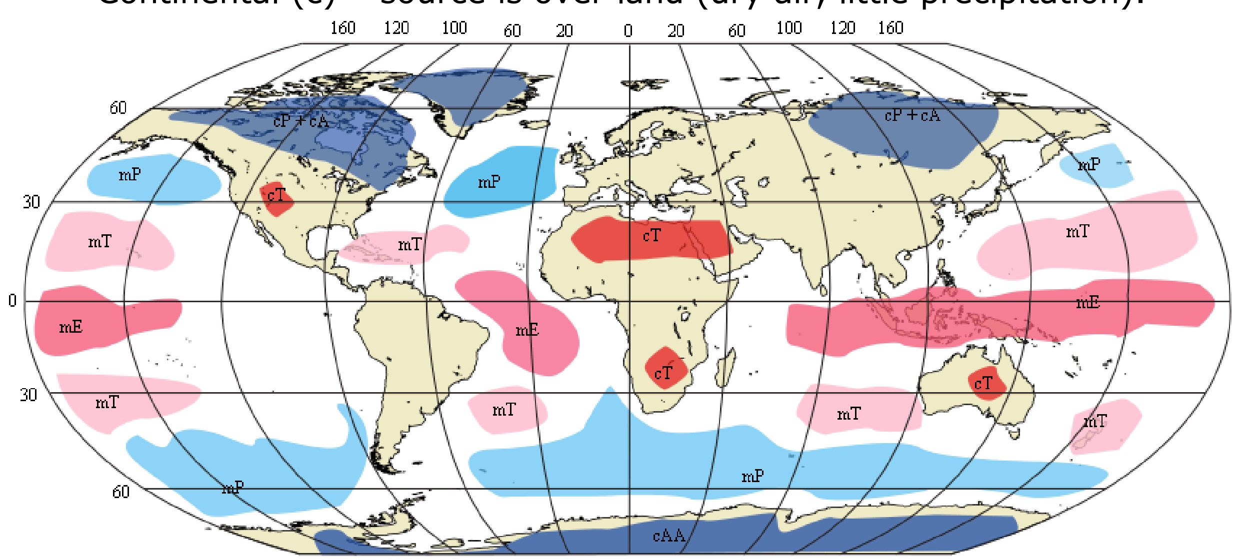


Air masses

Air masses are continental scale bodies of air, with uniform temperature and humidity characteristics. Some air masses are relatively static in terms of their position, but others move in response to short-term changes in atmospheric circulation.

Air masses are classified by their source areas:

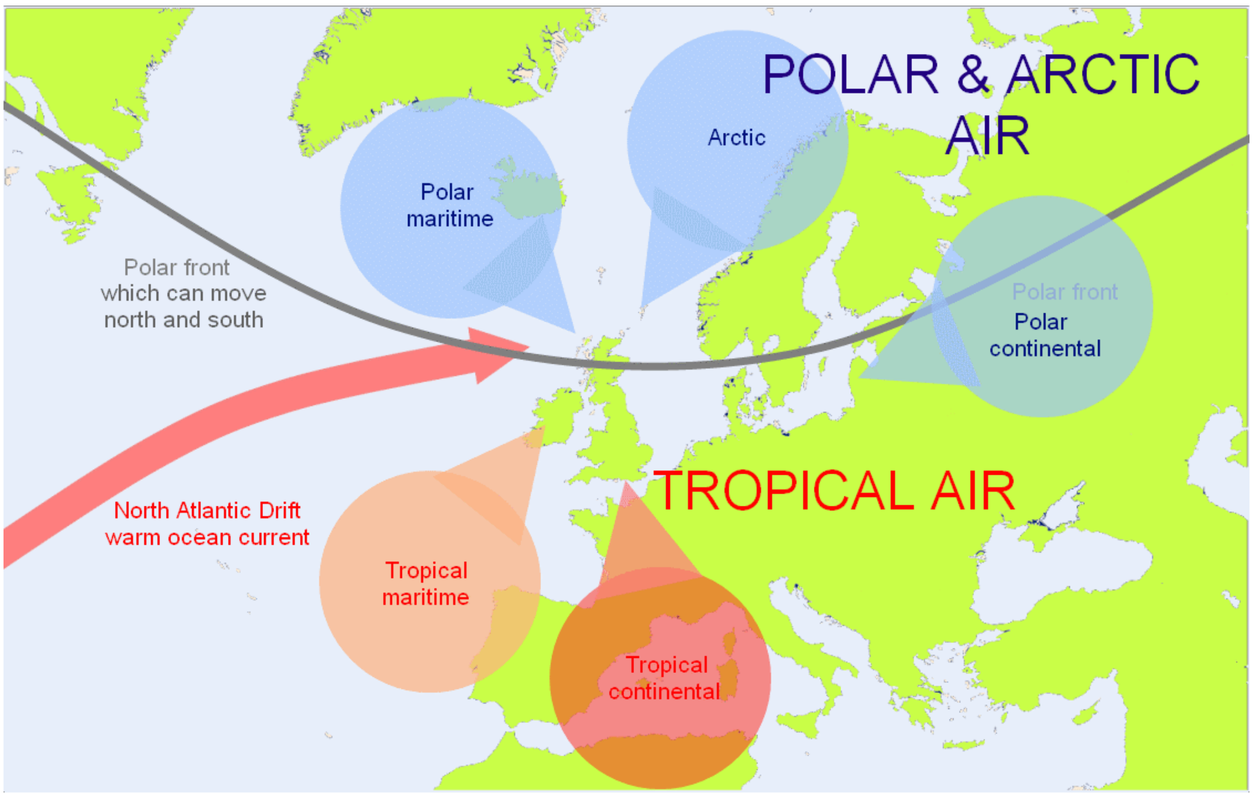
- Maritime (m) – source is over the oceans (humid air, precipitation).
- Continental (c) – source is over land (dry air, little precipitation).



- Arctic / Antarctic (A) – originating over the Poles (very cold).
- Polar (P) – originating in high-latitudes (cool).
- Tropical – originating close to the tropics of Capricorn and Cancer (warm).

- Equatorial – originating over the equator (hot and humid).

Air masses can **track** (move) out of their source areas and into areas nearby, bringing changing weather conditions. Some air masses become more **unstable** when they move into new areas. In **mid-latitude areas** such as Europe, North America, southern Australia / NZ air masses have a major influence on weather and are highly changeable. For instance, northern Europe lies at the **Polar Front** – the boundary between the Polar and Ferrel Cells – and the exact position of this front can alter which of the air masses influences particular areas at any given time:



Jet Stream and Rossby waves

The position of the Polar Front can be seen on the map of air masses above (there is also a southern hemisphere polar front). This position is highly variable and subject to change. A high altitude west-east wind called the **Jet Stream** follows the line of the Polar Front and takes the form of a meandering **Rossby Wave**.

Rossby waves change their form frequently and allow, for instance, tropical continental air to move up over northern Europe or polar continental air to move south-west bringing prolonged cold, dry weather far south into Western Europe.

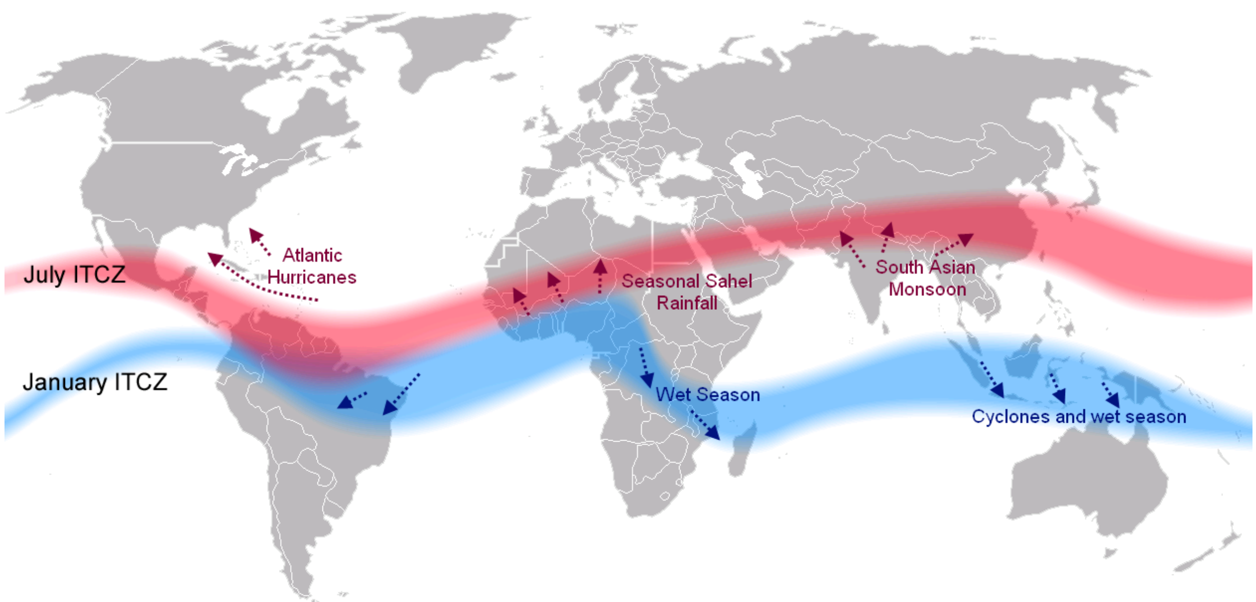
Search for 'Rossby waves' on www.youtube.com

Heat equator and ITCZ

The belt around the equatorial regions that receives maximum heating from the sun is known as the thermal equator or **heat equator**. This corresponds to the location of the ITCZ or **Intertropical Convergence Zone.** At the ITCZ:

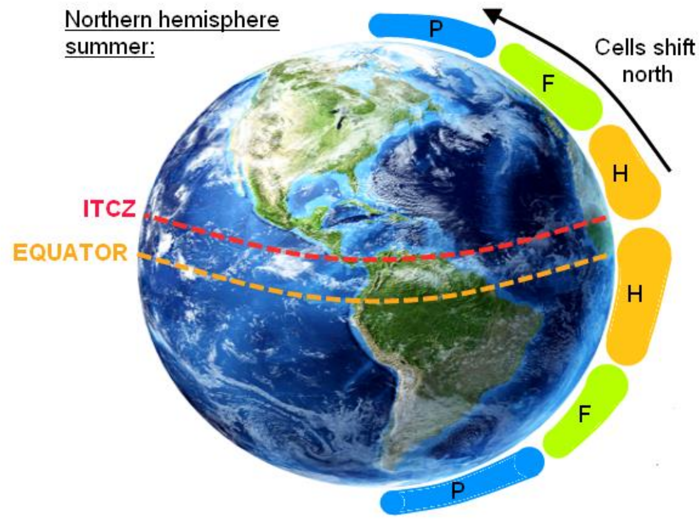
- The northern and southern hemisphere Hadley Cells meet.
- Warm air converges on this area at sea / ground level.
- The warm air rises creating area of persistent and strong convection, with low pressure, cloud and heavy rainfall.

The ITCZ does not follow the line of the geographical equator (0° latitude) because of the distribution of land versus ocean and how each responds to heating from the sun. Due to the earth's axial tilt and the progression of the seasons the ITCZ moves seasonally north and south. This has a major impact of weather systems worldwide as all 3 major atmospheric cells shift their positions:



The seasonal movement of the ITCZ is not fully predictable or the same each year, for instance:

- As it moves north through Sub-Saharan Africa and the Sahel it can 'stall' and fail to move as far north as usual – this can result in drought in areas that would normally get seasonal rains.
- A weak or shortened monsoon season in South Asia has been linked to variability in the ITCZ movement, as well as other factors such as the position of Jet Streams and ENSO events in the Pacific.



It is important to recognise that many people in both the developing, emerging and developed world's still rely heavily on seasonal rainfall for water supply and farming.
Seasonal rains are strongly influenced by the shift in the ITCZ and subsequent changes to atmospheric cells.

3.3.2 Extreme weather hazards

Enquiry question: What causes extreme weather events?

Mid-latitude depressions
Mid-latitude depressions are a common type of low-pressure weather system found between 25° and 65° north and south of the equator.
They are cyclonic weather systems (like tropical cyclones) with high wind speeds, heavy rainfall and in some case snowfall / blizzard conditions.
Mid-latitude depressions form:

- Over the ocean, for instance the North Atlantic.
- At the boundary zone between cool Polar Maritime air and warmer Tropical Maritime air (the Polar Front).

The process of formation is called **cyclogenesis** and it generates a weather system with multiple **fronts**. Fronts are boundary zones between air masses with different temperatures, humidities and densities and are associated with cloud cover, rainfall and often strong winds.

Mid-latitude depressions can become hazardous weather events especially when:

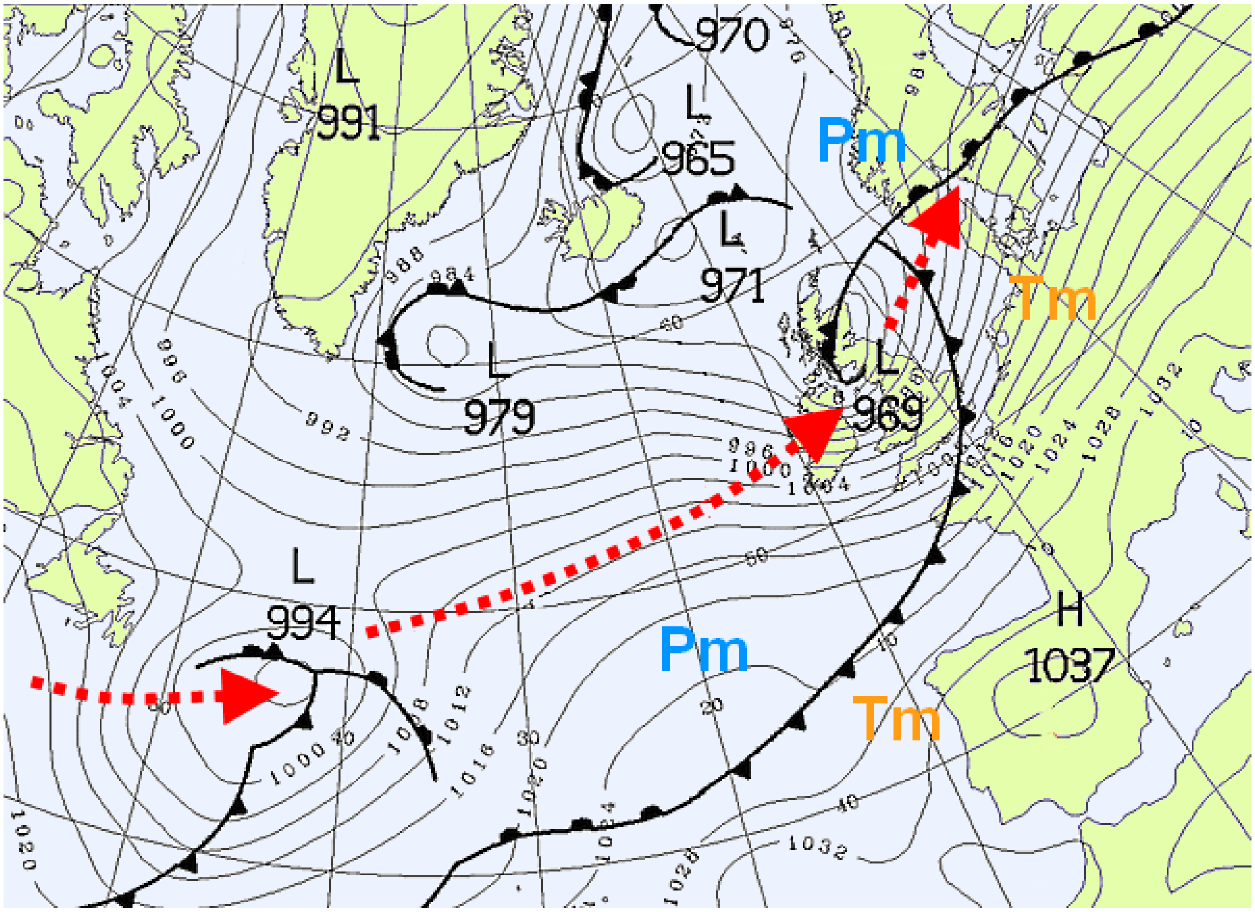
- There is a **large temperature difference** between Polar and Tropical air masses, which increases wind speeds and promotes rainfall.
- A **powerful Jet Stream** above the depression 'pulls' air rapidly up into the atmosphere, lowering air pressure at ground level and increasing wind speed.

Low air pressure can create **storm surges** in the sea, leading to coastal flooding.

Search for 'Depressions – Weatherbytes' on www.youtube.com

The UK Met Office has a number of case studies of extreme weather events which can be found here: https://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena/case-studies

Synoptic charts
A synoptic chart is a weather map showing current conditions in terms of air pressure and fronts, and sometimes other information.
This is an example of a typical synoptic chart for the North Atlantic in winter:



- There is a mid-latitude depression over the UK, with very low air pressure of 969 millibars.
- Tropical maritime air mass is to the south, Polar maritime to the north.
- The isobars (lines of equal air pressure) are tightly packed over the UK indicating very strong winds.
- The air wind circulation around the Low 969 is anti-clockwise.
- The depression has three fronts: a warm front is over southern Norway, a cold front over the east of the UK and an occluded front over Scotland.
- Rainfall is produced from each of the fronts, with strong winds linked particularly to the cold front.
- The depression will track north-east towards Norway and dissipate.
- Notice another depression (Low 994) to the west, which will move towards Europe.
- There is an area of high pressure – an anticyclone – over Spain with clockwise air circulation (High 1037).

High pressure weather systems can also be weather hazards. These weather systems are called **anticyclones**. They:

- Have clockwise air circulation in the northern hemisphere.
- Have light winds.

- Have clear skies, or limited high cloud cover and no (or very little) precipitation.
- Can be very persistent i.e. once formed they can 'sit' over regions for weeks or up to a month.

Anticyclones become hazardous when then become '**blocked**'. This usually happens because of a medium-term change in the position of the Jet Stream / Rossby Waves meaning that high pressure becomes stable over one area, and blocks low pressure weather systems from entering the area. Northern Europe and North America are susceptible to such anticyclones but they do have very different impacts in winter and summer:

Winter	Summer
• Clear skies and very cold temperatures; freezing fog • Any snow that does fall tends to lie and not melt • High levels of air pollution as subsiding air prevents pollution from dispersing • Health risks associated with prolonged cold.	• Clear skies and high temperatures; heat-wave risk • Short-term drought due to lack of rainfall • Elevated risk of grassland and forest fires • High pollution levels • Health risks with heat-stroke and dehydration, especially among the elderly.

Tropical cyclones

Although tropical cyclones are a cyclonic weather system much like a mid-latitude depression, the scale of tropical cyclone impacts are significantly larger.

- The 2017 Atlantic Hurricane season alone involved 10 hurricanes, close to 500 deaths and economic losses of over US$ 180 billion.
- In the Pacific, the 2016 Typhoon season killed 900 and led to economic losses of US$11 billion from 13 typhoons.

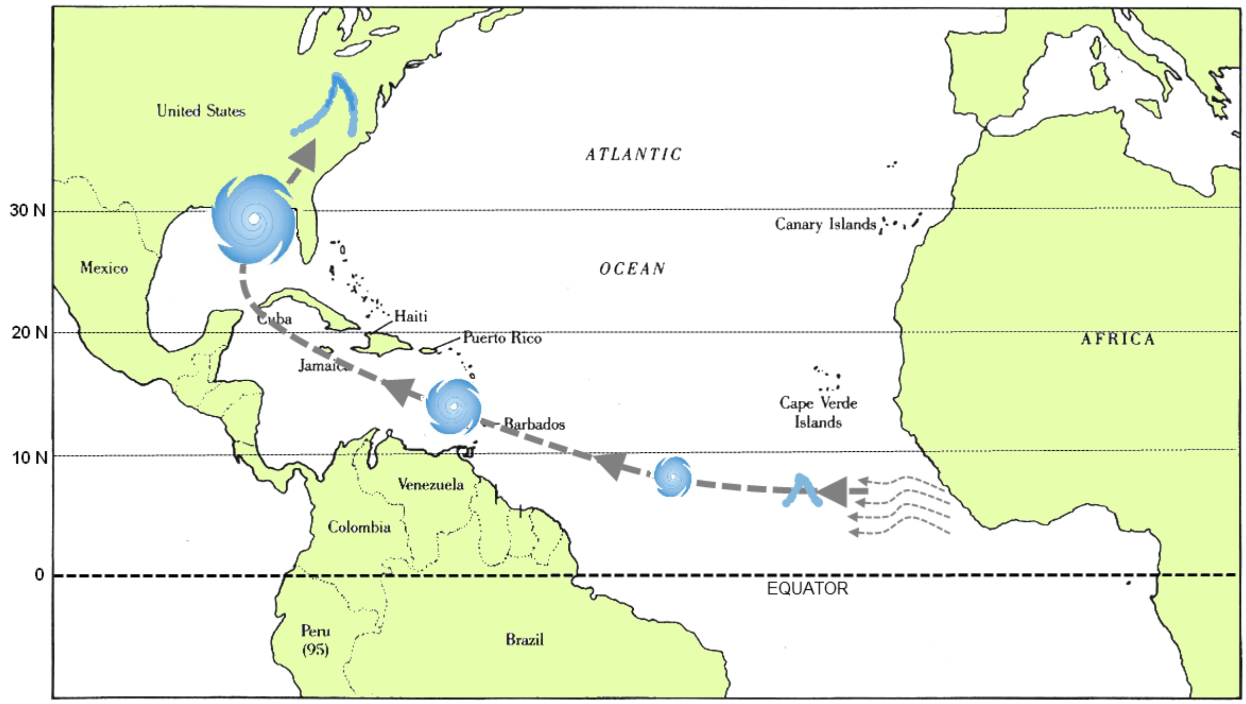
The crucial factor in tropical cyclone impacts is whether or not a storm makes **landfall**, and the extent to which the land hit is vulnerable i.e. low-lying and flood prone and / or populated by vulnerable people.

All tropical cyclones have three stages:

- Formation in source areas
- Tracking and intensification
- Landfall* and dissipation

*some tropical cyclones do not make landfall and dissipate over the ocean.

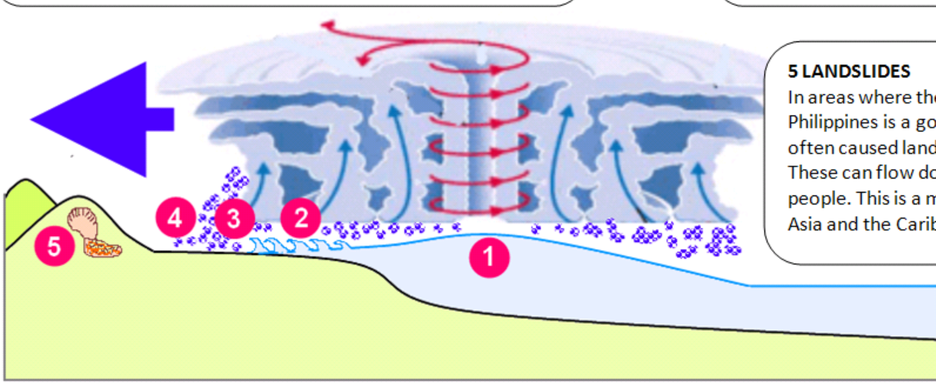
The map below shows these stages for a typical Atlantic Basin hurricane; in terms of timescale the whole process may take 2-3 weeks.



An important aspect of tropical cyclones is the fact that they generate **multiple hazards** when they make landfall, very strong winds are just one of their hazards:

1 STORM SURGE
The low air pressure at the centre of the storm increases sea level by 1cm for every 1 millibar drop in air pressure. As the cyclone moves towards land, the 'bulge' of water created by the storm surge is pushed onto land causing widespread coastal flooding to property and crops.

2 WAVES
Cyclone strength winds create huge waves.
These batter sea defences causing flood walls to collapse. Waves also increase the height of the sea even more, adding to flood risk.



5 LANDSLIDES
In areas where there are hills near the coast (the Philippines is a good example) the intense rain often caused landslides.
These can flow down slopes, burying houses and people. This is a major risk in some parts of SE Asia and the Caribbean.

3 INTENSE RAINFALL
Huge volumes of rain are produced by tropical cyclones.
The rain just adds to the water from the storm surge, and makes flooding even worse.
Rain can fall far inland, only to be carried back to the sea by rivers – and meet incoming storm surge flood waters on the way.

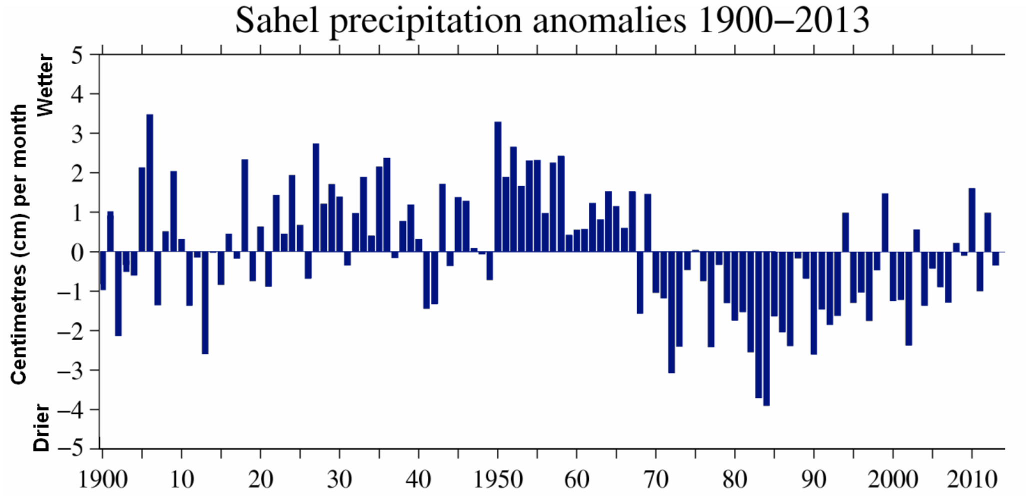
4 WINDS
Winds of between 90 and 150 mph are common. These can rip down trees, damage buildings and bring down power and telephone cables.
Localised tornadoes are quite common within a tropical cyclone, causing even more damage.

Drought
As a weather hazard, drought differs from mid-latitude depressions and tropical cyclones because it is a longer-term weather hazard. Drought builds over weeks, months and years before reaching crisis point in terms of water supply.

Drought, aridity and famine
Drought is a period of **below average rainfall** in a region, leading to water supply shortages (surface and /or groundwater) which then has an impact on farming and water supply for people and industry.
Arid areas i.e. deserts and semi-deserts ***normally*** lack rainfall but are not in a state of drought: drought implies abnormally low rainfall. **Famine** is a shortage of food, which is often caused by or exacerbated by drought. However, drought and famine are not synonyms.

Drought can be caused by a number of different changes to 'normal' rainfall pattern, including:

- **Persistent anticyclone conditions:** drought in the summer of 1976, in the UK, was partly caused by very high summer temperatures (high rates of evaporation) and high demand for water. However, more significant were anticyclonic conditions in the winter 1975-1976 which reduced winter rainfall and led to falling river and aquifer levels.
- **ITCZ / Seasonal rainfall failure:** drought can result from a weak or failed monsoon or wet season, often linked to unexpected changes to the ITCZ or monsoon airflows.
- **Long-term precipitation trends:** between the late 1960s and 2000 average rainfall in the Sahel region of Africa fell sharply creating persistent drought – this followed a period in the 1950s and 1960s of above average rainfall. It's likely that such trends are part of natural climate cycles, but may be affected by global warming.
- **El Nino / La Nina cycle:** these have been linked to drought in Australia and California, but the relationship is a complex one.
- **Landuse change:** deforestation and other changes to landuse can reduce evaporation, and soil moisture storage, and have the potential to make areas more arid than they once were.



University of Nebraska http://drought.unl.edu/DroughtBasics.aspx

3.3.3 Managing extreme weather

Enquiry question: How are the risks of extreme weather managed by different players and technologies?

Forecasting
Weather forecasting has a crucial role to play in managing extreme weather. Forecasts are essentially short term **predictions** of future conditions made up to 2 weeks into the future. Forecasts are fairly accurate 2-5 days ahead in mid-latitude areas but become increasingly inaccurate beyond 5 days. For a forecast to be '***actionable***' in terms of ordering evacuations or making emergency preparations before extreme weather hits it needs to be:

- Made long enough in advance, to allow mitigating actions to be taken e.g. 24-48 hours ahead.
- Be disseminated to people who can act on it.
- Be reasonably accurate i.e. so the right place are evacuated / helped in the right ways.

Inaccurate forecasts lead to '***cry-wolf syndrome'*** meaning a forecast turns out to be wrong, so the next forecast is assumed to be wrong also.

There have been several huge leaps in forecasting technology over the last 100 years:

Ground station data gathering	• Traditional weather stations measuring wind speed, direction, precipitation, air pressure etc. are now **automated,** sending real-time data to forecasters. • In the past they were manned, and relied on telephoning data to forecasters which was slow and error-prone.

Rainfall Radar	• Weather radar was developed in the 1960s and is used to track precipitation levels and predict the movement of fronts and cyclones.
Satellite technology	• Since the 1970s, satellites have been able to track storms from space, making predicting their future path easier. • Satellites can measure ground and sea surface temperature, soil moisture and many other parameters.
Computer modeling	• Forecasters use **supercomputers** to 'crunch' vast amounts of data in numerical forecast models. • These models produce numerous forecasts which are compared and filtered.

In the USA, 'hurricane hunter' Lockheed Orion aircraft fly into hurricanes to gather data on them. These are flown by the USA's NOAA (National Oceanic and Atmospheric Administration) an organization with an annual budget of US$5-6 billion. It's worth remembering that not all weather hazard prone countries have access to such technology and budgets.

UK Met Office weather forecasting:
https://www.metoffice.gov.uk/research/modelling-systems/unified-model/weather-forecasting

Players

Different groups and organizations – often called 'players' have a role in managing extreme weather events and trying to reduce the impact of disasters.

These groups work:

- **Before extreme weather events** – in terms of preparation, prediction and planning emergency responses.
- **During extreme events** – providing information, and immediate rescue and recovery.
- **After an event** – during the recovery and rehabilitation phase.

Planners	First Responders
Planners can reduce hazard impacts through land-use zoning e.g. preventing construction on flood prone areas. Zoning and building-codes need to be enforced to be effective. Planning is also needed in terms of physical defences, evacuation routes, information dissemination	The Police, ambulance and health services, fire service and in some cases military personnel all have a role in responding to disasters. In some cases, organizations like the USA's FEMA (Federal Emergency Management Agency) have a role in overseeing the response.

and permanent / temporary shelters. The role is essentially about preparation and mitigation, and requires funding and good governance to be effective.	Severe disasters may involve assistance from other countries. Funding, personnel and physical assets are needed to reach people in need and help them.
Community Groups Groups working with local communities have a role in education and preparation. This could include understanding warnings and evacuation routes, educating people about how to protect homes and which emergency supplies to keep at home. Building community resilience is a key part of improving hazard response.	**NGOs and aid organizations** These work in the developed, emerging and developing world. Even in the USA a large part of immediate response and recovery is in the hands of NGOs such as the Red Cross. In the developing world the role of international NGOs is often very significant after a major disaster.

Prediction, warning and evacuation

The **Hazard Management Cycle** (or Disaster Management Cycle) is an important concept in managing extreme weather events.

It stresses the idea that successful management in a continuous process that involves applying the lessons of one event to the preparation for the next.

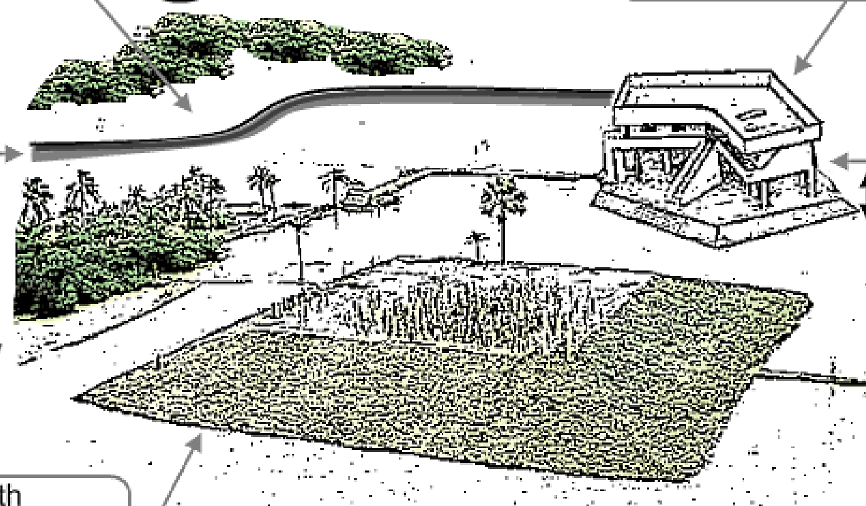
Perhaps the most crucial stages of this cycle are on the left: *mitigation, prevention, preparation, evacuation and warning* can all help **reduce vulnerability** and **increase resilience**.

70% of the population in the most high risk, coastal areas are landless labourers who work on farms and in shrimp lagoons

PER CAPITA GDP IN BANGLADESH IS **US$ 1600 p.c.**

Concrete cyclone shelters cost around £50,000 each. There are some **3000** in Bangladesh, with a need for some **5000** more to adequately protect the population. At least 10 million at risk people lack access to a shelter.

Dykes protect coastal land from flooding, but these are poorly maintained and afforestation is hampered by salt water encroachment.



Shelters need to be at least 6m above ground to withstand the cyclone storm surge

Research suggests cyclone sheltersare not used if they aremore than 1.5km from homes.

Cost of additional cyclone shelters needed: US$1.2 billion

A 'killa' is a raised earth mound used to protect cattle from the storm surge. Most are communal, many are poorly maintained. Finding land for new ones is very difficult.

Cost of additional killas = £20 million

<u>HOW CAN TECHNOLOGY HELP ?</u>

1. More cyclone shelters; these could be multi-purpose structures such as schools, which can also be used as temporary shelters.
2. Improved roads and tracks to shelters and killas.
3. Community construction on additional killas.
4. Mangrove and tree planting on dykes and coastal wetlands.
5. Education, so people know when to evacuate, and where to go.
6. Clearer cyclone warnings, and community based warning systems to disseminate warnings; upgrading of the ageing radio warning system.

Tropical cyclone response in Bangladesh

There are many interesting developments in cyclone response, many of which relate to the spread of new technology, including:

- **The use of mobile phones / smart phones** – which have spread rapidly in the developing and emerging worlds – allow warnings and information to be disseminated rapidly and widely.
- The **internet** allows people to access information about storms, track them and decide on a response rather than relying on traditional media.
- Technology and **social media** allows NGOs to make appeals for aid easier than ever before.
- **GPS and GIS** technology is widely used in search and rescue efforts to make tracking areas searched, reporting damage and managing response more efficient.

Engineering
There are a number of ways in which **hazard-resistant design** and hard engineering can be used to resist the **power of cyclones** and **storms**. Hazard resistant design can take many forms:

- In cyclone prone areas, especially in coastal locations at risk from storm surges houses can be built on stilts (or the ground floor is used for storage, garages etc. not for habitation) – both 'high-end' homes in Florida and in the developing world.
- In some parts of coastal Bangladesh houses can be quickly dismantled and moved in pieces to embankments to hopefully beat the storm surge.
- Cyclone shelters – which in Bangladesh are increasingly used as schools (i.e. dual purpose) – are often the only concrete structure for miles around, but can off course resist a cyclones flooding and winds.

The temptation is to go further and try and prevent storm surges flooding coastal communities by using **hard engineering** coastal defences like levees (artificial embankments), flood gates and flood walls. This approach has a number of problems:

- Costs are very high: likely to be in the region of $5000-10,000 per metre of flood defences.
- Construction is very difficult: low-lying coastal swamps, marshes and wetlands are tidal (restricting construction time) and hard to build foundations on.
- Defences may involve destruction of coastal ecosystems – these often act as natural coastal defences so removing them is short-sighted.

- Sea-level rise predicted from global warming may render defences useless in only a few decades.
- If defences fail (as in hurricane Katrina in 2005) the resulting floods can be catastrophic: levees encouraged building in areas that were below sea-level.
- Defences have high annual maintenance costs.

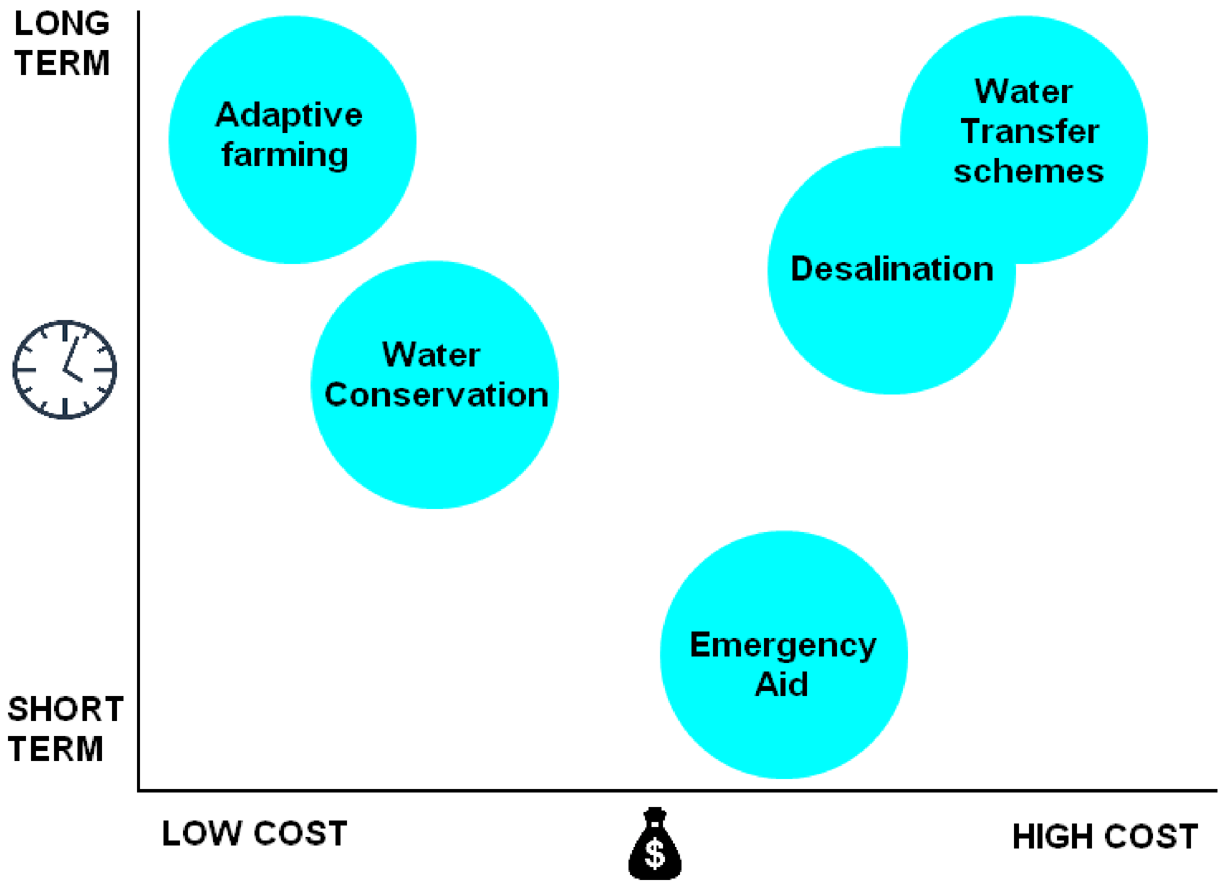
Managing drought

Drought can be managed in a number of ways. Because drought is basically about water supply there are two possible approaches:

1. Increase supply
2. Decrease demand

In the case of **increasing supply,** this usually involves long-term, capital intensive schemes to acquire more water. This includes desalination plants – a response taken by Australia to the long-term drought 2000-2010 – and also water transfers such as China's South-North Scheme. The construction of dams and reservoirs is a similar approach. These approaches may not be suitable everywhere due to high costs. In addition they do not deal with the fundamental problem.

Decreasing demand means using water in a smarter way, so it goes further. Water conservation is such a method and is really about changing attitudes to water and how it is used i.e. seeing it as a scarce resource.

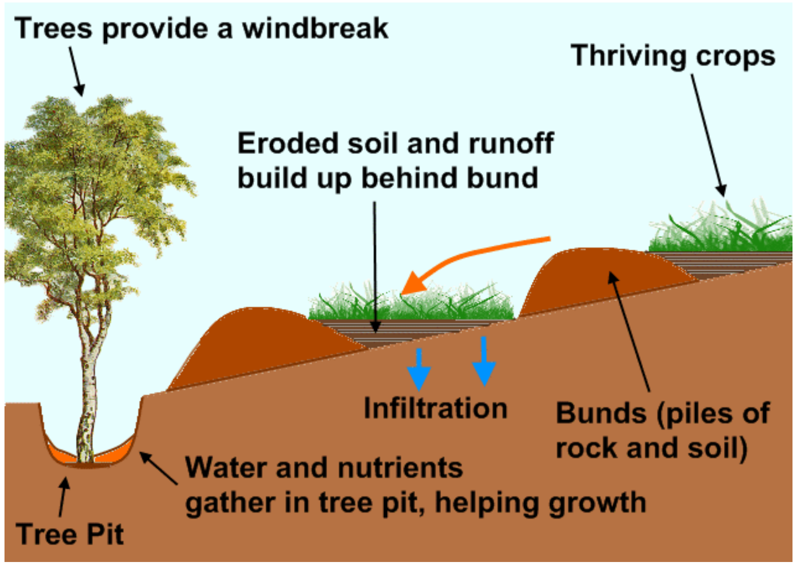


Perhaps the worst approach is **short-term, emergency aid.** This is usually needed when a drought has turned into a crisis of both water and food supply. It has caused people to migrate out of drought-stricken area and created a humanitarian crisis.

These situations could be seen as failures to act earlier, when warning signs were present. Such crises are likely in areas such as the Sahel and parts of South Asia where many people still rely on rain-fed farming for subsistence. In these areas, **adaptive farming** is a long-term low cost solution that in many cases can reduce the impact of drought.

In the future this might involve drought-tolerant GM crops, but today it usually involves intermediate technology to make better use of what little water there is and built **resilience** into food production systems so they can cope with drought.

The diagram below shows how bunds (sometimes called 'banquettes' or 'magic stones') and tree pits can be used to increase infiltration when it does rain, and reduce erosion from wind an occasional torrential rain. These types of basic technology are often used by communities in the Sahel with support from local and international NGOs.



Governance
The concept of governance is important in the management of extreme weather events. **Governance** means the way a country or region is run on a day-to-day and long-term basis. It includes how **money is spent** (fairly, efficiently, in a non-corrupt way), how **services are run** (health, education, emergency services) and how **decisions are taken** (in the interests of the majority, or a few).
Poor governance:

- Decreases coping capacity, because services are absent or ill-run.
- Limits response, because those that could respond are under-funded / poorly managed.
- Limits recovery, because resources are likely to be scare and subject to corruption.